Tactical Decision Aids
(High Bandwidth Links Using Autonomous Vehicles)

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LONG-TERM GOALS

The goals are to develop Tactical Decision Aids for using small autonomous underwater vehicles in very shallow water (VSW) environments. TDAs enable operators to view data gathered by these vehicles and make informed decisions as to the conduct of mine counter measures operations. This project is examining the use of command and control vehicles to aid in reducing latency of decision making and improvements to overall MCM reliability using multiple vehicles. A large part of this work is to reduce latency of decision making using systems of AUVs and high speed, high bandwidth communications links.

OBJECTIVES

The objectives of this FY 2004 year work were to demonstrate high bandwidth communications links between multiple vehicles. This included both underwater, surface and aerial vehicles, equiped with 802.11 wireless bridges and amplifiers. The objectives were to transfer video sized files at high rates leading to the use of full video data for target evaulation and decision making. In these experiments, forward looking sonar files are collected by the NPS ARIES AUV and transferred through the high bandwidth link to a command center.

APPROACH

The operational requirements for developing this technology are:

- Robust communications for command and control and data transfer are required for teams of vehicles deployed in an area to scout and report on oceanographic conditions and the mine threat
- Collected data is voluminous and requires a high bandwidth data link
- Data needs to be collected and distributed quickly for rapid operational planning
- Not all vehicles may return from missions – the data still needs to be collected.

The solution offered by this technology provides unmanned systems with high bandwidth communications (currently 802.11b) using a UAV as a bridge between an AUV and a

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command cell located some distance from the AUV. The technology also automates the path of the UAV to optimize the link between the groups of vehicles.

WORK COMPLETED

This year NPS participated in 4 exercises, the Surveillance and Target Acquisition Network (STAN)-5, 6, and 7 exercises, and the Combined Joint Task Force Experiment (CJTFEX) 04 exercise, held at Camp Lejeune, NC. These exercises form a continual series of developments that include both an opportunity for experiment as well as a demonstration of ever increasing levels of autonomy and networking complexity and speed. The STAN experiments are funded separately by USSOCOM and NPS and form a natural way to multiply the results and effectiveness of the work funded by this project.

RESULTS

Stan-5 (February, 2004- Camp Roberts, CA.)

NPS ARIES was fitted with 802.11b CISCO 3150,radio ether net bridge and a similar bridge on a V6 TERN aerial vehicle. During this experiment, File Transfer data was demonstrated between the ARIES vehicle and the TERN at various ranges. Experiments were conducted using 3 dbi, 5dbi, omni and directional antennae, as well as a 1 watt amplifier inside ARIES and the TERN. File transfer data were gathered and demonstrated at a range of 1 km., for a flight altitude of 300-500 ft with data rates between 160 and 300Kbps.

Stan-6 (May 2004, Camp Roberts, CA)

In this experiment ARIES was operated in Lake Nacamiento with a tethered balloon, as well as the TERN aerial vehicle. ARIES was located in the Lake approximately 11km from the Command Center at MacMillan field. The surfaced ARIES transmitted a video sonar data file to the TERN operated by USSOCOM, V-6 forces controlled to fly autonomously over Lake Nacamiento. File data was received at the Command Center as soon as the TERN was seen circling above the Lake. Data transfer rates were variable but averaged about 300K bps. Key to the success of the experiment over this range was the use of the high gain receiver and a tracking antenna (K2) at the Command Center to track the TERN. Similar experiments were conducted using a tethered balloon as the relay link. So long as the balloon was visible at MacMillan Field Command Center, the file transfer

was made. High winds occasionally reduced the balloon height so that the link bandwidth was reduced when line of sight was lost. Occasional outages simply slowed the overall net rate, but the link was not destroyed.

CJTFEX-04-2 (June 2004, Camp Lejeune, NC)

A complete report of the activity during CJTFEX 04-2 is given in [1] and is beyond the scope of this report to describe all aspects of the work. In a quick summary, the ARIES AUV was equipped with the Cisco AERONET 350 802.11b wireless bridge for high data rate transfer using a 1 Watt compatible antenna, and an aerial vehicle- TERN carried a separate bridge package. The TERN, which crashed on first flight, was substituted by a Balloon. Data gathered over various ranges from the surface AUV through the Balloon relay and a high gain tracking antenna (K2) showed solid performance and data rates to 300Kbps over ranges up to 20Km.

Figure 1. ARIES AUV Being Deployed at Camp Lejeune (Yellow Fin Carries 802.11b Antenna (1 Watt)

Figure 2. TERN

For CJTFEX 04-2, Navy Composite Squadron SIX (VC-6) used the TERN and its Ground Control Station. For CJTFEX 04-2, the payload was the NPS bridge.

The balloon deployed to 1000feet, and its payload is shown in Figure 3.

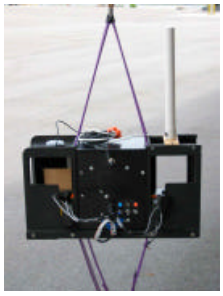

Figure 3 Balloon Payload Balloon and K2 Tracking Antenna

The NPS objectives for the ARIES/TERN System during CJTFEX 04-2 were:

- Demonstrate high bandwidth links for sonar and/or video file transfer between the ARIES AUV, the TERN UAV and the K2 Tactical Operations Center
- Demonstrate 802.11b network links for AUV and UAV assets over distances greater than 4km at 200-300 kbps.

Tests were conducted on 7 and 9 June to determine the maximum range of the 802.11b link. Tests were conducted on 6 and 8 June to determine the file transfer rates of various network configurations.

The NPS Aries/Tern mission was a qualified success. The mission demonstrated the ability to create a stable 802.11b network with three nodes with a total length of 27km. Data files were moved along the network at file transfer rates ranging at a maximum of 800 kbps down to 160 kbps at maximum node separation (max range).

The primary objective of these ONR observations is to assess the military utility and application of participating OMCM FNC systems in a real-world exercise environment. It appears that 802.11b technology does represent one means of providing a high bandwidth (200 to 800kbps) link between autonomous and unmanned vehicles and other network nodes using standard Windows networking. The architecture is relatively simple to set up, uses COTS components, and is relatively secure.

Stan 7 (17-20, August 2004, Monterey Bay, CA and Camp Roberts CA.)

These experiments, while far from complete, demonstrated the use of very high bandwidth data relays from a surfaced ship at 12km out in Monterey Bay to Camp Roberts over 100 miles away with data rates up to 6 Mbps. This ultra high speed was obtained using OFDM communications protocol under the 802.16 Standard. While the equipment is not yet miniaturized for deployment in small AUVs, the capability was demonstrated well offshore [4].

Related Work

In related work, CAPT. Jack Nicholson completed his Doctoral dissertation [2], dealing with Autonomous Rendezvous between Autonomous Underwater Vehicles for the purposes of close in formation flying to transfer high speed data underwater at close range. High bandwidth underwater may be eventually possible at short range. Experimental work validated the use of autonomous planning and re-planning using energy and time optimal concepts. Also tied to this project is the work in Obstacle Avoidance control for the REMUS AUV under the assumptions of perfect detection of underwater obstacles. Vertical plane detection and avoidance has been reported in [3], following the work of earlier thesis students reported in FY 03.

TRANSITIONS

High speed data transfer using 802.11 and 802.16 technologies is expected to transition into the Navy's UUV acquisition program in the future.

RELATED PROJECTS

The related project is titled "NPS ARIES Forward Look Sonar Integration" in which a small Blazed Array is used for obstacle detection.

REFERENCES

[1] Marshall, P., Valdez, T., "ARIES-TERN Network Connectivity Experiment Quicklook Report ', Naval Postgraduate School, Monterey, CA. June 2004.

[2] Nicholson, J. W., "Autonomous Rendezvous of Autonomous Underwater Vehicles", Ph.D. Dissertation, Naval Postgraduate School, September 2004

[3] Healey, A. J., "Obstacle Avoidance While Bottom Following for the REMUS Autonomous Underwater Vehicle", Proceedings of the IFAC IAV-2004 Conference, Lisbon, Portugal, July 2004.

[4] Marshall, P.M., Valdez, T., Moellering, R., "Surveillance and Tactical Acquisition Network Exercise No. 7, At-Sea OFDM Network Connectivity Experiment, Quicklook Report", Naval Postgraduate School, August 2004.

HONORS, AWARDS, PRIZES

Professor Healey was awarded the Distinguished Professor Award at NPS this year, and was selected to be the Chairman of the Mechanical and Astronautical Engineering Department at NPS.